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was successful in artificial impregnation and in tracing the histories of the various segmentation planes. The first plane is longitudinal, and for many stages an alternation of rest and activity on the opposite sides of this plane is noticeable. Thus at one time almost every nucleus on the left side shows distinct mitosis figures, while not a single nucleus of the right side exhibits such a feature. This was witnessed again and again, until the blastoderm contained 116 cells.

CRUSTACEA.—Professors W. K. Brooks and F. H. Herrick describe (*J. H. U. Circ.*, No. 70) some features in the development of the Peneid form *Sergestes hispidus*. It escapes from the egg as a protozoa, passes soon to the true zoea stage, and then to a mastigopus condition.

GENERAL.—Dr. H. V. Wilson gives an account (*J. H. U. Circ.*, No. 70) of the times of breeding of several marine forms at the Bahamas, which will prove of value to students visiting the West Indies.

WORMS.—Dr. Hurst records (*Notes from Leyden Museum*, January, 1889) the presence of *Arenicola cristata* (originally described by Stimpson from South Carolina) at Naples.

EMBRYOLOGY.

THE ORIGIN AND MEANING OF SEX.¹—My hypothesis respecting the origin and meaning of sex may be stated provisionally as follows, pending a fuller sketch to be published in the immediate future.

1. Over-nutrition is regarded as the prime cause of the un-

¹ Seventeen paragraphs, or those numbered 1, 2, 8, 9, 12 to 18, 21, 22, and 25 to 28, of this article comprise all except 154 words, *verbatim et literatim*, of the first draft of a synopsis of the hypothesis here somewhat more fully presented. The Secretary of the Academy of Natural Sciences, of Philadelphia, advised the withdrawal of that first draft, which was offered for their *Proceedings*, on the ground that it was unwarrantably anticipated by the publication of the same matter in a supplementary notice, which was privately published by the author, with the same title, dated July 5, 1889, and which also forms part of the present article. This note is necessary in order to correct any possible erroneous impression which may have arisen in the minds of those to whom copies of extras were sent of the first article, as to the latter's source, as it was printed, in advance of the issue of the signatures of the Academy's *Proceedings*, and bore the imprint of the latter.

equal growth of cells, or of individuals, if the latter are unicellular.

2. The differentiation of sexuality as a result of such unequal nutrition, through which a difference in potential of segmentational power was developed in consequence of physiological differentiation, accompanied by a great difference in size.

3. Over-nutrition in animals and plants has led to all the forms of sexual, asexual, and parthenogenetic reproduction.

4. The over-nutrition of ova, ovules, etc., through which they have grown beyond the average size of the other cells of the body of the parent, is proof that they have in some way lost the power to undergo spontaneous segmentation, except in the case of parthenogenesis, which will be dealt with more fully hereafter.

5. Over-nutrition of the male mother-cells, accompanied by an exaltation of segmentational power, has caused their products to become the smallest cells produced by the body, with a concomitant augmentation of latent segmentational power.

6. Ovum and spermatozoon are not homologous, but only sperm-mother-cells or groups of them and ova are homologous; the same law applies to the germ-cells of plants.

7. The production of the definitive sexual elements of the multicellular forms has proceeded *pari passu* with an extreme physiological differentiation of karyokinetic function in the two kinds, which stand in a reciprocal relation to each other, and which has been the cause of their reciprocal attraction for each other, leading to the act of fertilization.

8. The ability of such over-nourished cells to go on segmenting only as result of the union of such pairs of unequal dimensions, which stand to each other in a reciprocal relation of potentiality as respects segmentational power. The female cell has lost the power to spontaneously segment, whereas the male cell has acquired an exaltation of latent segmentational power.

9. The integration of such large masses of living matter as single units made it possible for the results of such segmentations to cohere, instead of falling apart. If, in fact, such preparatory accumulation of material had not occurred, rapid, simultaneous and successive segmentations would have been impossible, since *pari passu* with the differentiation of their segmentational function such germ-cells finally lose *in toto* the power to nourish themselves except when in a relation of continuity with the parent organism.

10. The aggregation of large masses of segmentable plasma has also enabled the products of such simultaneous and successive segmentations to cohere and remain a multicellular aggregate, and to thus lay the foundations and become the direct cause of all metazoan and metaphytic organization.

11. The over-nutrition of the female element and the augmentation of its mass has rendered possible complex series of simultaneous and successive segmentations, in planes of from one to three dimensions, and the development of embryos without need of other nutriment during the preliminary or larval stages of ontogeny, thus leading also to the evolution of all larval forms.

12. So long as living organisms remained unicellular they were enabled to vary and become adapted only within the narrow limits determined by their unicellular condition, yet we know how marked is variability, even in this low grade of development; proportionally far greater than in multicellular types.

13. The achievement of the multicellular condition, as I have supposed, produced new and more complex morphological relations leading to the manifold differentiation of physiological functions in relation to diversification of surroundings, thus introducing a new and most powerful cause or capacity for variations and adaptations under such diverse conditions.

14. It is thus seen that the evolution of sexuality is the indirect cause of variability, and that otherwise there could have been no such thing as a struggle for existence leading to natural selection amongst multicellular organisms—at least seeing that they must have been produced, according to this hypothesis, as a result of the development of sexuality.

15. Over-nourishment in the vegetable, then lead to the over-nourishment of the animal world and the over-production of germs or young in both, so that the rate of increase became augmented in a geometrical ratio, as supposed upon the Darwinian hypothesis, which, on the basis of the theory of the struggle for existence and the process of natural selection so evoked, accounts for the preservation of valuable or advantageous variations through survival and inheritance.

16. Over-nourishment, then, is, according to the present hypothesis, regarded as the primary cause of morphological differentiation under the stress of diverse conditions, as well as of the geometrical ratio of increase of such forms, and, consequently, of the struggle for existence.

17. The doctrine of over-nutrition consequently becomes

antecedent to that of Darwinism, since it accounts for the primary diversification of species on the basis of inequalities of cell-nutrition in all forms, thus seizing upon the diversification of the physiological powers of the primal forms of life as the first factors in biological evolution, and which gave the latter its first impulse and upon which all further impulses have been superimposed.

18. Sexuality is thus rendered the motive force of all biological development, but in a totally different sense from that hitherto held by any one else.

19. While sexuality thus viewed becomes the motive force of all biological evolution it also gives rise to the means of variability and a greatly augmented fertility of individuals, thus also leading to the struggle for existence and natural selection.

20. Sexuality is therefore found to transcend in importance the principle of natural selection itself, since over-nutrition only could have led to the over-production of germs and the consequent increase of individuals in a geometrical ratio, as assumed by the Darwinian hypothesis, and, since the vegetable world stands in an annectant relation between the not-living and animal world, it can be understood how the latter came to be over-nourished.

21. This hypothesis further assumes that, with the gradual circumscription and localization within more and more restricted limits, of the production of germ-cells, and *pari passu* with morphological differentiation, that the reproductive and recapitulative powers of the other cells of multicellular organisms became gradually less and less marked, owing to the gradually more intensified expression of the principle of the physiological division of labor in the evolution of organs with more and more definite functions.

22. It regards the hypothesis of the immortality and immutability of the *Keimplasma* as inadequate, and as absolutely disproved by the facts of morphological development alone.

23. The production of germ-cells has been localized more and more definitely as a result of the increasing morphological specialization of multicellular forms, so that the hypothesis which assumes that the germ-plasma is precociously set aside in order to render it unmiscible with the somatic plasma, and therefore immortal, is based upon a fundamental error of interpretation of the facts of morphology.

24. The only cells in the multicellular forms which are ab-

solutely otherwise functionless are the germ-cells. They alone, therefore, can become the vehicles for the transmission of all the traits of the parent in higher forms, since they alone are otherwise functionally unoccupied, and are the only cells of the body which, by any stretch of the imagination, can be supposed, *a priori*, to possess the recapitulative power manifested in ontogeny.

25. It further assumes that the theory of the geometrical ratio of increase is qualified by the advent of multicellular forms as a direct result of the development of sexuality, and that, reckoning on the basis of cell generations, the ratio of increase in the animal and plant world is absolutely and relatively less than if living forms had remained unicellular.

26. It leads also to the assumption that biological evolution has been along definite lines, and not fortuitous or hap-hazard, as has been tacitly or avowedly assumed by some incautious but extreme partisans of the doctrine of natural selection.

27. This hypothesis is based on the assumption that the undifferentiated nucleated cell is the point of departure for all morphological and physiological differentiation, and that the first depends upon the character of the karyokinetic changes which go on within it, while the second depends upon the nature of its metabolism and the mechanical arrangement and constitution of the plasma through which such metabolism is manifested.

28. Upon this ground may be based a further development of hypothesis which gives a satisfactory explanation of parthenogenesis, pædogenesis, gemmation, temnogeny, metagenesis, and the recapitulative processes of ordinary sexual genesis.

29. In the production of female germs (ova, oospheres,) there occurs a prolonged process of intergration of plasma to increase the volume of the cell-body. In the production of male elements, (spermatozoa, antherozoids,) on the contrary, an actual process of elimination of plasma occurs, so as to reduce the cell-body to a minimum size and leave little remaining except the nucleus and its chromatin. The modes of production of the male and female elements therefore, stand in the most extreme contrast in respect to each other.

This hypothesis, founded upon data which have been hitherto apparently ignored, applies to both the animal and vegetable kingdoms, sex having probably arisen simultaneously

and independently in both, as soon as certain cells of coherent groups become over-nourished and incapable of further segmentation unless brought into contact and fused with the minute male elements, or one which, as we have seen, is the product of an exalted segmentational power which is transferred to the female element in the act of fertilization. Both kinds of sexual products were probably at first, and still continue to be, dehiscenced from the parent organisms as useless products of over-nutrition, after further recapitulative growth in the form of new axes or of individuals, growing in organic union, as in colonial organisms, became impossible, due to crowding, the culmination of seasonal growth or the morphological specialization leading to definite or constant formal individuality.

All the facts which I have been able to gather lead to the conclusion that there is a relation between the difference in size of the male and female elements as to the number and rapidity of the subsequent segmentations of the resulting oö sperm or oö sphere. If the elements are alike there will be comparatively few segmentations; if greatly unlike, many successive segmentations seem possible.

The foregoing hypothesis affords clues to the reasons for variations in the fertility of species, the origin of viviparity and placentation, the infertility of irrelated forms, the origin of food yolk in ova and of pelagic eggs, the evolution of primary and secondary sexual characters, the interrelations of plants and animals, and a consistent and simple theory of inheritance, which is in harmony with all the facts of reproduction in plants and animals.

This hypothesis also discloses some of the apparent reasons why there is so frequently a great difference in the size of the sexes, as in fishes, where the male is smallest, and especially in those arthropodous forms, in which the males are microscopic and attached to or parasitic on the females, as in some Copepoda and Cirripedia. The extraordinary feeding and nursing habits of social Hymenoptera, efficient in determining the sex or neutrality of offspring, also acquire a new significance.

The first steps by which the over-growth of the sexual elements through over-nourishment is seen in the most primitive of all known non-parasitic, free-swimming, multicellular forms, namely, *Volvox*. Its life history proves that the multicellular condition can be, and probably was, attained directly by the over-growth and subsequent segmentation of a single cell in

three planes, simultaneously and successively, with but little coherence, forming a delicate blastula, the cells of which are separated from each other by interspaces, and joined together by very slender protoplasmic bonds. Certain cells of this blastula-like organism grow directly into germs with exaggerated dimensions. The wall of the *Volvox* blastula is probably ectodermic and entodermic in its homologies, gastrulation is still to occur, but it is interesting to observe that already the germs are produced in a little more than one hemisphere only, which probably corresponds to the ectodermic portion of a Cœlenterate, while the empty, anterior, directive, and sensory pole is homologous with the entoderm of the latter. The tendency of the germ-cells to originate from the ectoderm in some Cœlenterates, therefore, may have an ancestral significance.

The over-growth of Protozoan or Protistan forms probably gave rise, through a series of segmentations, directly to such types as *Volvox*, and simulating the planula or blastula more or less closely. Gastrulation, under its various guises, as well as proliferation and delamination, also followed, with their consequences, which led to the direct development of the various forms of ciliated larvæ, at once ready to feed, undergo metamorphoses, and share in the struggle for existence.

This first larval development was probably rapid, and due to the same causes as are still seen to be operative in the development of ova, namely, rapid segmentation. The accumulation in the egg of a mass of plasma in excess of the average of its fellow cells or individuals, laid the foundation for the first and most primitive type of segmentation, namely, the holoblastic, before any yolk was added to the ovum, as is seen in the development of *Volvox*. This coherent aggregate was now an individual, ready to begin the struggle for existence, and with infinite capacity for variation, and with an augmented power of reproduction.

The ovum, according to this hypothesis, becomes the conservative factor in biological evolution in a new sense, while the male element imparts the power to undergo rapid segmentation, and to quickly achieve the larval state, when the interaction of the organism and the environment can be brought into play. The physiological activities of such plasmic aggregates as an oöspERM are at first almost wholly karyokinetic, and but slightly metabolic; this renders possible the later and immediately subsequent anabolism through which further growth and

power is acquired. In the vegetable world there has, from the first, been a tendency to form plates, filaments, and later columns of cell aggregates, instead of the blastula form of animal types. Sexuality, or the development of male and female elements, therefore, has a meaning, fraught with consequences and promises which have culminated in the most wonderful morphological and adaptive specialization, and probably in definite ways, which might have been predicted had all the conditions been known.

N. B.—Finally, it is necessary to point out here that these views have little in common with those urged by Geddes. While a preponderance of anabolic activity may produce an ovum, as he supposes, how it is possible to conceive that processes of physiological disintegration or katabolism, such as are witnessed in the breaking down of protoplasm into simpler compounds, could result in the production of male-cells, I utterly fail to comprehend. That growth is accompanied by katabolism there is no doubt, but to assume that the tremendous energy with which karyokinesis manifests itself in spermatogenesis is merely an exhibition of preponderant katabolism, which must result in the enfeeblement of the cells so produced, stands in such obvious contradiction to all that we know of the male-cells, that such an erroneous view must be unhesitatingly pronounced inadequate and unfounded. Anabolism and katabolism, or the molecular processes by which protoplasm is built up and torn down, cannot be tortured into an equivalency with the widely diverse modes of manifestation of karyokinetic activity in the morphologically homologous ovum and sperm mother-cells.

The fundamental error lies in confounding ordinary physiological processes with special modes of the manifestation of karyokinesis, and since there is no other known instance of katabolism resulting in the breaking up of cells by rapid cleavage into small cells, such as those produced from spermatoblasts, it may well be doubted if the equivalency sought to be established is anything more than fanciful.—*John A. Ryder.*

PHYSIOLOGY.¹

GASKELL'S WORK.—The most important recent work on the physiology of peripheral nerves, is that of Dr. W. H. Gaskell, of Cambridge, which has occupied him during the past ten years.² Begun as a contribution to cardiac physiology, it has extended itself much beyond this, and bids fair to alter fundamentally our conceptions of the morphological and

¹ This department is edited by Dr. Frederic S. Lee, Bryn Mawr College, Bryn Mawr, Pa.

² Gaskell's chief articles are published as follows—

Phil. Trans. 1882. p. 993.

Journal of Physiology. Vol. IV. p. 43.

“ “ Vol. V. p. 362.

“ “ Vol. VII. p. 1.

Medico-Chirurgical Transactions. Vol. LXXI. (Contains a summary of results up to the receipt of the Marshall Hall Prize.)

Journal of Physiology. Vol. X. p. 153.